Evaluation of Root and Canal Morphology of Maxillary Permanent First Molars in a North American Population by Cone-beam Computed Tomography

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Abstract

Introduction: The purpose of this study was to evaluate the number of roots and canal morphology of maxillary permanent first molars in a North American population. **Methods:** Three hundred seventeen cases with bilateral maxillary first molars were included. All images from cone-beam computed tomography were carefully reviewed by 2 endodontists. Frequency of number of roots, presence of an additional mesiobuccal canal (MB2), and Vertucci canal type for each root were tabulated. Age, gender, and ethnicity differences were calculated with the χ^2 test. The intra-rater reliability was assessed by using the Cohen kappa statistic. **Results:** The fused root rate was 0.9%. The occurrence of 3-rooted maxillary first molars differed between left and right sides ($P = .03$). MB2 occurrence only showed statistically significant differences among age groups ($P = .005$). In the mesiobuccal roots, the most common Vertucci classifications of canal types were type IV (2-2, 41.9%), type I (1, 28.3%), and type II (2-1, 26.3%). There was a statistically significant difference in Vertucci classification of canal type among 5 ethnic groups (African American, Asian, Hispanic, Other, and Non-Hispanic white, $P < .001$). **Conclusions:** Cone-beam computed tomography facilitates the identification of root and canal configuration. The information gained about the tooth anatomy and canal morphology before treatment could potentially facilitate root canal therapy. *(J Endod 2014;40:635–639)*

Key Words

Cone-beam computed tomography, root canal morphology, tooth anatomy

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Complete knowledge of internal root morphology has been an important issue in planning and executing root canal therapy (1). Successful treatment requires clinicians to have a basic knowledge of root canal morphology and possible anatomic variations (2). Many efforts have been made in the *in vitro* examination of root canal morphology by using the tooth-clearing technique with the naked eye (3–5) or with the aid of a microscope (6). Micro–computed tomography (micro-CT) is an advanced radiologic technique that provides nondestructive evaluation of root canal morphology and root anatomy (7). Micro-CT has been generally considered as a reliable approach to analyze root canal anatomy (8). However, all the *in vitro* techniques (tooth-clearing technique or micro-CT) can only be applied to extracted teeth, limiting the applicability of these techniques in clinical practice and being incompatible with root canal therapies where the goal is to save the tooth.

In vivo methods include periapical radiographs and cone-beam computed tomography (CBCT). Periapical radiographs provide only 2-dimensional information of 3-dimensional structures, which might lead to misunderstanding of root anatomy because of superimposition of roots (9). CBCT has been shown to be a good method for initial identification of maxillary first molar internal morphology (1, 9, 10). Filho et al (9) compared *ex vivo* (140 extracted teeth), clinical (291 patients), and CBCT approaches (54 randomly selected teeth) for the number of additional root canals and their locations, the number of foramina, and the frequency of canals. Fifty-four maxillary first molars examined with CBCT had 4 canals (37.05%), and 90.9% of the teeth that had additional canals comprised 1 foramen, whereas 9.1% comprised 2 foramina. The authors indicated that operating microscope and CBCT have been important for locating and identifying root canals, and CBCT can be used as a good method for initial identification of maxillary first molar internal morphology (9). Plotino et al (11) compared 161 maxillary first molars, 157 maxillary second molars, 117 mandibular first molars, and 161 mandibular second molars to establish the symmetry in root and canal anatomy between left and right sides by using CBCT scanning. A percentage of symmetry that varied from 70% to 81% was reported. The authors suggest taking into high consideration the asymmetry of canal configuration when treating 2 opposite molars in the same patient. CBCT scanning could also facilitate the identification of rare canal configurations according to the authors. Martins et al (12) reported 2 rare cases of C-shaped configuration in upper first molars by using a dental operating microscope. CBCT scanning was used, and the same canal configuration on the opposite tooth was identified.

Number of roots and canal morphology may vary by gender, age, or ethnicity (1, 10, 13, 14). Sert and Bayirli (1) used the tooth-clearing technique and examined 200 maxillary first molars (100 from male and 100 from female patients). The prevalence of additional mesiobuccal canal (MB2) was 35% for male and 30.2% for female patients. Kim et al (10) used CBCT to evaluate the morphology of maxillary first and second molars in a Korean population. The authors found that having additional canals in the mesiobuccal root is the most common variation in maxillary molars (63.6% in 3-rooted maxillary first molars and 34.4% in 3- or 4-rooted maxillary second molars), and the root and canal configuration of this Korean population was different from other studies (10). Pattanshetti et al (13) treated 110 3-rooted maxillary first molars in Kuwait. Of those, 58% had 1 canal in the mesiobuccal root and 42% had 2 canals, with a high occurrence of Weine type II canal configuration (2-1) in the Kuwaiti population. The

authors also indicated that all distobuccal and palatal roots had 1 single canal (13). Zheng et al (14) examined 775 maxillary first molars in a Chinese population and indicated that the occurrence of MB2 decreased with age. Reis et al (15) demonstrated the effectiveness of CBCT scanning in mapping MB2 canals present in different thirds of the root. A total of 343 teeth (79 right and 79 left maxillary first molars and 94 right and 91 left maxillary second molars) from100 male and 100 female patients were analyzed *in vivo* by using CBCT scanning to identify root number and the presence of MB2 canals in different thirds. The authors indicated that the prevalence of MB2 canals decreased as the root canal approaches the apical third and as age increases.

The prevalence of MB2 in the United States population has been evaluated by using *in vivo* observations with the aid of microscopes (6, 16) or with the *ex vivo* tooth-clearing technique (5). Stropko (6) examined 1096 conventionally treated maxillary first molar records and found the prevalence of MB2 was 93.0%, with the aid of a dental surgical microscope. Sempira and Hartwell (16) treated 130 maxillary first molars by using a microscope to record the occurrence of MB2, and the prevalence of MB2 was 33.1%. The authors indicated that a surgical microscope did not increase the number of second mesiobuccal canals located when compared with those reports without microscope use. Ibarrola et al (5) evaluated 87 extracted maxillary molars and decalcified the mesiobuccal roots to observe the occurrence of MB2, and the prevalence was 77%. However, to our knowledge, little effort has been dedicated to the examination of number of roots and canal configuration of maxillary permanent first molars in North America by using CBCT.

The aim of this study was to evaluate the differences in number of roots and canal morphology of maxillary permanent first molars according to gender, age, and ethnicity in a United States population by means of CBCT images.

Materials and Methods

Subjects

CBCT images of maxillary first molars were collected from 1484 patients who had undergone CBCT scanning for orthodontics or implant treatment planning at the Redmond Imaging Center, Ostrow School of Dentistry, University of Southern California between July 2007 and July 2012. The research protocol was approved by the Institutional Review Board of the University of Southern California (#UP-13-00024).

Inclusion Criteria

The following cases were included in the study:

1. Bilateral maxillary permanent first molars
2. Fully matured and erupted bilateral maxillary permanent first molars
3. Molars without root canal fillings, posts, crown restorations, apical periodontitis, or any other odontogenic or non-odontogenic pathology

Exclusion Criteria

Molars with fused roots were excluded because of the difficulty of identifying mesiobuccal, distobuccal, and palatal roots.

Radiologic Evaluation

All the CBCT images were acquired with a Sirona Galileos device (Sirona Dental Systems, Inc, Long Island City, NY). The technician acquired a fixed field-of-view volume of 15 × 15 × 15 cm. The 3-dimensional resolution (isotropic voxel size) was 0.3/0.15 mm. The scanner was operated at 85 kV and 5–7 mA. The Digital Imaging and Communications in Medicine (DICOM) format images were exported from Galileos and imported into InVivo Dental Application 5.1.6 software (Anatomage Inc, San Jose, CA).

Serial sagittal, coronal, and axial views of CBCT images were examined carefully by 2 endodontists independently until an agreed diagnosis was reached for each case. The DICOM images were examined, and the number of roots, the number of root canals, and the canal morphology (defined by the classification of Vertucci [17]) were tabulated for each maxillary first molar. Gender, ethnicity, and age were also collected. Twenty randomly chosen cases (40 teeth) were examined and diagnosed a second time by the same 2 endodontists 2 weeks apart, and the intra-rater reliability was calculated by using the Cohen kappa. Agreement was noted as excellent if $\kappa \geq 0.75$, good if $0.60 \leq \kappa < 0.75$, intermediate if $0.4 \leq \kappa < 0.60$, and poor if $\kappa < 0.4$ (18).

Statistics

The prevalence of 3-rooted maxillary first molars was calculated. Descriptive statistics (age, ethnicity, gender) were calculated. The Pearson χ^2 test was used to analyze the differences in prevalence of 3-rooted maxillary first molars between left and right sides and by gender. Differences by age in prevalence of MB2 were also analyzed with the χ^2 test. Differences by ethnicity in canal morphology were examined by using the Fisher exact test. SAS software 9.3 (SAS Institute Inc, Cary, NC) was used in this study, with a significance value of $\alpha = .05$.

Results

The intra-rater reliability was 0.81 (excellent).

One thousand four hundred eighty-four CBCT scans were examined for inclusion criteria. Three hundred seventeen cases with bilateral maxillary permanent first molars met all the criteria and were included in the study. The average age of the patients was 40 years, among whom 161 were female patients (average age, 38 years) and 156 were male (average age, 42 years). Among these 634 maxillary first molars, 6 (0.9%, 6 of 634) were 2-rooted, and 628 (99.1%, 628 of 634) were 3-rooted. No single-rooted maxillary first molar was detected. Fused root molars were excluded because of the difficulty of identifying mesiobuccal, distobuccal, and palatal roots. Examples of different canal morphologies are shown in Figure 1.

Prevalence of 3-rooted Maxillary First Molars on Left and Right Sides

The prevalence of 3-rooted maxillary first molars was higher on the right side (100%, 317 of 317) compared with the left side (98.1%, 311 of 317) ($P = .03$).

Prevalence of 3-rooted Maxillary First Molars According to Gender

Regardless of side, the prevalence of 3-rooted maxillary first molars in female patients was 50.8% (319 of 628) and in male patients was 49.2% (309 of 628). The overall occurrence of 3-rooted maxillary first molars in female and in male patients showed no statistically significant difference.

Percentage of MB2 Canal in 3-rooted Maxillary First Molars According to Age, Left and Right Side, and Gender

The prevalence of bilateral MB2 occurrence was 65.6% (208 of 317 cases). The overall occurrence of MB2 in 3-rooted maxillary first molars was 68.2% (428 of 628 teeth). The frequency distribution of MB2 by 6 age groups (10–20, 20–30, 30–40, 40–50, 50–60, and